MANITOBA CANADA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

MAN 2 CREDA

Canada

MANITOBA

PREPARED BY:
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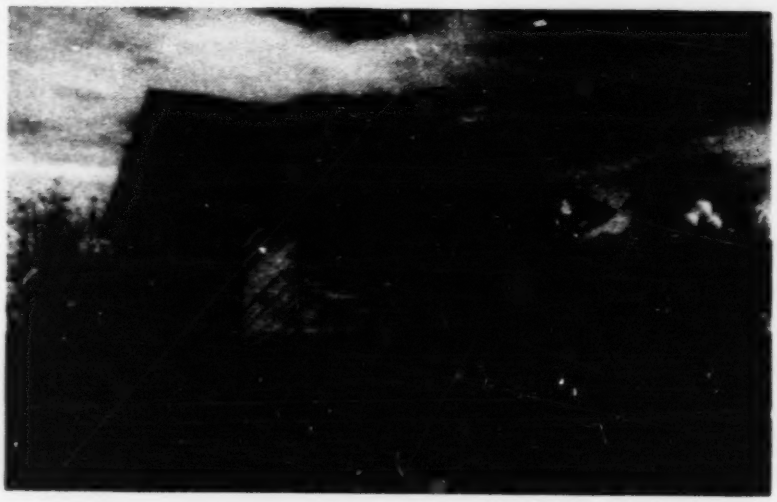
MANITOBA DEPARTMENT OF ENERGY AND MINES



ENERGY EFFICIENT HOUSING

KENSINGTON HOMES - WINNIPEG

MANITOBA/CANADA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources - oil and natural gas - are becoming less accessible and more costly. However, Canada is well-endowed with non-renewable and alternative resources that can provide a bridge into the future.

To this end, the governments of Manitoba and Canada have entered into a Conservation and Renewable Energy Demonstration Agreement which was signed May 9, 1980 and terminates March 31, 1984. The Agreement is dedicated to the development and demonstration of conservation and renewable energy technologies. Equally cost-shared by the provincial and federal governments, the program has a total budget of $18-million.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- To develop broad public awareness of the potential of renewable energy and conservation technology.
- To provide opportunities for the commercial application of the technologies within Manitoba.
- To create economic spin-off benefits for manufacturing, industry and commerce.
- To create employment in new or existing energy-related industries.

EXECUTIVE SUMMARY

Construction of the Kensington Homes energy efficient house was funded jointly by Canada and Manitoba under the Federal/Provincial Conservation and Renewable Energy Demonstration Agreement (CREDA).

The purpose of this project was to demonstrate to other builders and to the public that energy efficient features can be included in high volume construction at reasonable expense.

Kensington adapted a conventional 87 square meter house design to double wall construction withincreased insulation in walls and ceiling areas. Other energy saving features incorporated were; continuous vapour barrier, increased basement insulation, triple glazing maximized on south exposure, and an air to air heat exchanger for ventilation. The house is heated by four electric baseboard heaters with a maximum total rating of 3.8 KW.

House construction was monitored by UNIES Ltd., Consulting Engineers, of Winnipeg, who also performed air leakage testing. The final measured air leakage rate was 0.28 air changes per hour at 10 Pascals pressure differential for the completed home which compares very favourably with other energy efficient houses.

The importance of monitoring, and careful attention to vapour barrier sealing and weatherstripping was demonstrated during the construction. Achievement of adequate sealing could be a problem in high volume construction.

Based on UNIES" heat load analysis, a simple payback period of approximately 15 years was calculated for the cost of energy conserving features, assuming current electrical rates.

RÉSUMÉ ADMINISTRATIF

La construction d'habitations à faible consommation énergétique par les établissements "Kensington Homes" a été financée en commun par le Canada et le Manitoba grâce à l'entente fédérale-provinciale de démonstration des énergies renouvelables et des économies d'énergie.

Ce projet avait pour but de démontrer aux autres entrepreneurs et au public qu'il est possible de construire en série et à des prix raisonnables des habitations à faible consommation énergétique.

La compagnie Kensington a adapté un modèle de maison ordinaire de 87 mètres carrés avec des murs à double épaisseur et une isolation accrue à l'intérieur des murs et du plafond. Les autres moyens utilisés pour économiser l'énergie étaient les suivants: un pare-vapeur continu, accroissement de l'isolation du sous-sol, multiplication des triple fenêtres sur la face sud, et un échangeur thermique air - air pour la ventilation. Le chauffage de la maison est assuré par quatre plinthes chauffantes électriques dont la puissance maximale totale est de 3 kW8.

La construction des maisons fut contrôlée par Unies Ltd, entreprise winnipegoise d'ingénieurs-conseils, qui fit aussi le test de fuite d'air. Dans la maison terminée, le taux final de changement d'air était de 0.28/h sous une pression différentielle de 10 pascals - ce qui est un bon résultat par rapport aux autres habitations à faible consommation énergétique.

Au cours de la construction, on put démontrer l'importance jouée par le contrôle et par les soins attentifs apportés au scellage dans l'installation d'un pare-vapeur et au calfeutrage. La qualité du scellage pourrait constituer un problème dans la construction en série.

En se basant sur l'analyse d'utilisation thermique faite par "UNIES", on a calculé qu'au tarif actuel de l'électricité il faudrait une simple période de 15 ans pour récupérer le coût de l'installation de conservation énergétique.

I. INTRODUCTION

Kensington Homes Ltd. of Winnipeg, Manitoba, received funds under the Federal/Provincial Conservation and Renewable Energy Demonstration Agreement to construct an energy efficient home.

The basic concept of their proposal was to adapt the more cost effective features of the Manitoba Energy Conservation House (MECH)[1] to one of their existing house designs. The purpose of the project was to demonstrate to other builders and to the public that energy efficient features could be incorporated into high volume construction.

UNIES Ltd., Consulting Engineers, of Winnipeg, were contracted to monitor construction and advise Kensington on energy efficient building techniques. UNIES performed air leakage tests on the structure and provided a heat load analysis to evaluate the effectiveness of the additional energy efficient features.

1. The MECH was designed by UNIES Ltd., Consulting Engineers, as described in "Specification for Manitoba Energy Conservation House" dated August 28, 1979.

II. BUILDING DESCRIPTIONS

2.1 General

The house was built by Kensington Homes and is located at 15 Crittenden Corner in Winnipeg.

A number of energy saving features were incorporated - high insulation levels, continuous vapour barrier and triple glazing. The front of the house, which has the most glazing, faces a south direction. An air to air heat exchanger is used to reclaim heat from vented house air.

2.2 Building Areas

The gross floor area is 87 square meters above grade, plus 87 square meters below grade. Room sizes are shown in the plan sketches (Figures 1 and 2, and Appendix A).

The gross exposed outside wall area, including windows, is 153.3 square meters.

2.3 Exterior Walls (see Appendix A, Figure A3)

Exterior walls are 12 inch (30.5 cm) thick, and of double 2x4 stud construction. The exterior wall surface is finished with stucco on three sides. The front is finished with cedar siding for decorative purposes.

2.4 Basement (see Appendix A, Figure A3)

Basement walls are 12 inches (30.5 cm) thick with 2x8 studs, 16 inches (40.6 cm) on centre, acting as structural members. Below grade, outside sheathing is faced with 6 mil polyethylene.

The floor structure consists of a plywood sub fastened to joists resting on sleepers over 6 mil polyethylene on a gravel fill foundation.

A general observation of the monitoring engineers is the apparently higher air leakage through the wood basement than would be expected in a concrete basement. However, this leakage was not so high as to be of major concern.

The use of a preserved wood foundation was found to facilitate the application of batt type basement insulation.

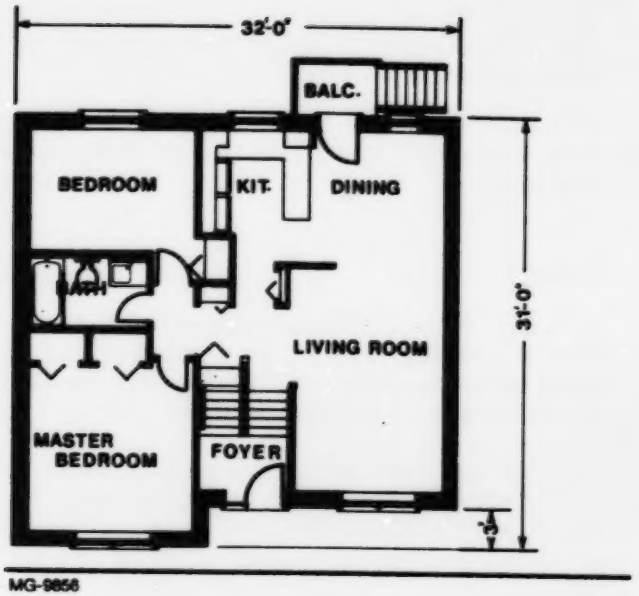


FIGURE 1 - MAIN FLOOR PLAN

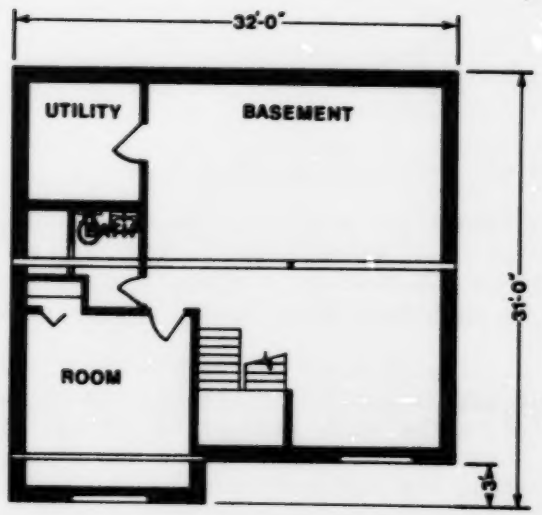


FIGURE 2 - BASEMENT FLOOR PLAN

II. Building Descriptions (Continued)

2.5 Ceiling and Roof

The roof is supported by "raised heel" trusses installed on 24 inch (61 cm) centres. The raised heel design allows 20 inches (50.8 cm), (R60) of fiberglass batt to be installed across to the exterior wall (Figure A).

Peak vents are installed in the gable ends to provide attic ventilation

2.6 Windows

Although triple glazed windows with 13 mm airspacing were specified, triple glazing with 10 mm airspaces was installed due to supply problems. According to UNIES, this would increase window heat loss by 5% to 15% (see Section V).

Glazing has been maximized on the south-facing side (5.3 sq. m. total area). The potential solar gain is offset somewhat by smaller north-side windows (1.7 sq. m. total area) and a doorway that were dictated by the floor plan. There are no windows on the east or west walls.

2.7 Insulation

Walls and ceiling are insulated with glass fibre batts, to the following levels:

	RSI	R
Above-grade walls	6.6	38
Basement walls	5.4	31
Ceiling	10.6	60

Doors are insulated to RSI 1.8 (R10).

These levels are well above those recommended by the 1978 Manitoba Building Code, which requires R33 in the ceiling, R12 in the walls and R7 to two feet (0.61 meters) below grade. Levels are however consistent with many super energy efficient houses recently constructed.

The building is enveloped with 6 mil polyethylene vapour barrier, sealed with acoustical caulking. In the wall sections this is installed on the outer side of the inside studs (Figure A3, Appendix A). This construction allows wiring and plumbing to be laid in without disturbing the vapour barrier.

II. Building Descriptions (Continued)

2.8 Lighting

Lighting in the home is provided by incandescent lamps. Fluorescent lamps would be more energy efficient, however, their colour balance was not judged pleasing in the house environment.

Fixtures were installed in the ceilings of most rooms. This is not recommended for energy efficient construction because the ceiling vapour barriers must be broken for wiring installations.

III. HEATING AND VENTILATION SYSTEMS

3.1 Heating

Four electrical baseboard heaters are situated about the house, as described in Table I.

TABLE I

Heaters in Kensington Home

Location	Electrical Ratings		
	Watts		Volts
Living Room	1130	@	208
Master Bedroom	750	@	208
Rear Bedroom	565	@	208
Basement	1320	@	208

Heat circulation depends upon natural convection and the operation of the air to air heat exchanger system.

Domestic hot water is electrically heated in a conventional energy efficient tank.

3.2 Ventilation

Tests of the completed Kensington home showed a very low air leakage rate due to effective vapour barrier, weatherstripping and caulking (Section 4.2).

III. Heating and Ventilation (Continued)

3.2 Ventilation (Continued)

Because of the increased sealing it was necessary to provide a ventilation system. An Enercon air to air heat exchanger exhausts stale air and moisture while preheating incoming fresh air. The exchanger is located in a corner basement laundry room with intake and exhaust vents positioned on adjacent faces of the outside corner of the house, according to convention at the time of construction, to reduce mixing of incoming and exhaust air. Current theory suggests that vents should be located on the same wall (approximately 3 m apart) to reduce the effect of unequal wind forces.

IV. AIR LEAKAGE TESTING

4.1 Air Infiltration

While all houses experience uncontrolled air leakage, energy efficient designs seek to minimize this by use of continuous vapour barrier, weatherstripping doors and windows, and by other sealing techniques (see Appendix B).

The degree to which these techniques have been successfully applied in a house can be measured using a blower door assembly. This induces and measures air leakage into houses at various pressure differentials between indoor and outdoor air (see Appendix B for further description and diagram).

These tests allow calculation of data that can be compared between various structures, and allows standards to be set.

The number of air changes per hour (AC/hr) is one of the useful calculated values that allows the tightness, and thus the energy efficiency, of a house to be estimated.

4.2 Test Results

Two air leakage tests were performed on the structure at the following stages of construction:

1. vapour barrier installed, interior not finished
2. completed house (see Appendix C for data).

4.2 Test Results (Continued)

The leakage rates (expressed in changes per hour, AC/hr) are reported below at pressure differentials of 10 and 50 Pascals. This is equivalent to 15 and 32 km/hr. winds, rspectively, over the entire house envelope.

Test Number		AC/hr. 10 Pascals	50 Pacals
1.	Incomplete interior	1.42	3.88
2.	Completed house	0.28	0.84

Both tests were conducted according to standard practices at that time,ie. with all doors and windows shut, all plumbing lines sealed, and both heat exchanger vents covered.

A dramatic reduction in air leakage was obtained after completion of the house. This is more likely the result of the builder rechecking and repairing the vapour barrier after the first leakage test, rather than due to additional finishing layers inside the house. The first test pointed out several major sources of infiltration.

- tears in the main floor wall vapour barrier which occurred during installation of the polyethylene.
- cuts in the ceiling vapour barrier which occurred during installation of the ceiling drywall.
- leakage around the access hatch to the basement sump.
- cracks between adjacent plywood sheets in the wooden basement floor.

The builder was able to seal these leaks satisfactorily, for instance by:

- sealing the sump hatch with polyethylene.
- filling the cracks in the basement floor with acoustical sealant and covering with carpet.
- repairing tears with polyethylene and acoustical sealant.

4.2 Test Results (Continued)

The final leakage rates place the house in a low energy category as Table II indicates.

TABLE II

House Description	Air Change Rate @ 50 Pascals
"Leakiest" home	33.3
Pre 1945 construction*	10.4
1945-1960 construction*	4.6
1961-1980 construction*	3.6
Low Energy Home*	1.5
Kensington Home	0.84
"Tightest" Home (at the time)	0.37

* Based on air leakage tests performed on 176 homes by the National Research Council of Canada

V. DESIGN HEAT LOSS AND ANNUAL HEATING LOAD ESTIMATES

UNIES Ltd. performed an analysis of the structure using the HSLD and HSUNPR computer programs. (Note that these programs were later combined and expanded to form HOTCAN, which is becoming the most extensively used residential energy analysis program in Canada). The results indicated that the design heat loss was 4,249 watts (14,500 BTU/hr) at an outside temperature of -33°C (-27°F). The distribution of heat losses at the design point is as follows:

Walls	14%
Ceilings	7%
Windows	19%
Doors	2%
Basement Walls Above Grade	8%
Basement Walls Below Grade	6%
Basement Floor	28%
Air Infiltration	15%
	99%

The annual heating load was estimated at 3,748 kW.h (13 x 10^6 BTU) or 43.0 kW.h/m^2yr. At the present electrical run off rate of 2.53¢/kW.h, the heating bill would be $94.84 per year, assuming a "standard" occupancy. This makes a number of assumptions concerning occupancy and lifestyle. These will vary considerably from family to family.

The estimated monthly heating loads and solar fractions (defined as the percentage of the total load met by solar gains) are given below.

V . Design Heat Loss and Annual Heating Load Estimates (Continued)

Month	Estimated Heating Load (KW.h/month)	Solar Fraction (%)
January	1062	29
February	734	40
March	438	55
April	71	81
May	0	100
June	0	100
July	0	100
August	0	100
September	0	100
October	21	91
November	485	36
December	937	25

VI. POST-CONSTRUCTION MONITORING

The house was used as a show home until early 1983. Electrical bills are kept, but these are not representative because:

1. The house was empty and temperatures were not consistently regulated.

2. Use patterns fluctuated according to the frequency that the house was shown. Electrical consumption is high in winter months when the home was shown a great deal (doors are typically left open during a showing).

No moisture or condensation problems have occurred, which may indicate a proper combination of sealing, insulation and ventilation. Again, however, as no occupancy period monitoring has been performed final judgement of performance in this area must be reserved.

Collection of data for the occupancy period April, 1983 to March, 1984, is planned.

VII. ECONOMIC ANALYSIS

Since reliable, representative electrical consumption figures for the occupied home are not yet available, the annual heating load estimate (Section 5) is used. For comparison, the consumption is used for a similar sized home constructed prior to 1975. The average for a pre 1975 home is 270 kW.h/square metre/year.

Cost of heating pre 1975 home 270 kW.h/sq.m./year x 87 x 2.53¢/kW.h	=	$ 594.00
Cost of heating Kensington Home 3,748 kW.h x 2.53¢/kW.h.	=	95.00
Project Savings		$ 499.00

The cost of building the Kensington home was $55,000, of which the increment for energy saving features was about $7,500, according to the builder.
Based on covering the incremental cost the simple payback period can be calculated as:

$$\frac{\$7,500}{\$499/\text{year}} = 15 \text{ years}$$

VIII. CONCLUSIONS AND RECOMMENDATIONS

1. The general quality of the energy related components of the completed house (insulation, vapour barrier, air management system, etc.) are very good. The thermal insulation appears to have been properly installed with no major problems. A relatively tight structure was achieved as illustrated by the low values for air leakage measured on the completed house.

2. The necessity of repairing the vapour barrier in the Kensington home points to a potential problem of achieving a good seal in high volume construction. This particular situation may be attributable to the builder's lack of prior experience with energy efficient construction.

   Nevertheless, high energy efficiency requires great care in building the seal and this operation can be time and labour intensive, defeating some of the cost advantage of high volume construction. Greater care must also be taken to prevent breeching of the seal during subsequent finishing operations.

3. Adoption of further energy efficient construction methods, such as wall mounting of all lighting fixtures,could reduce the possibility of vapour barrier breakage.

4. The lack of suitable conditions for running a meaningful post-construction monitoring restricts the ability to produce an adequate cost benefit analysis. It appears that a simple payback period of about 15 years may be expected on the energy efficient features incorporated into this design.

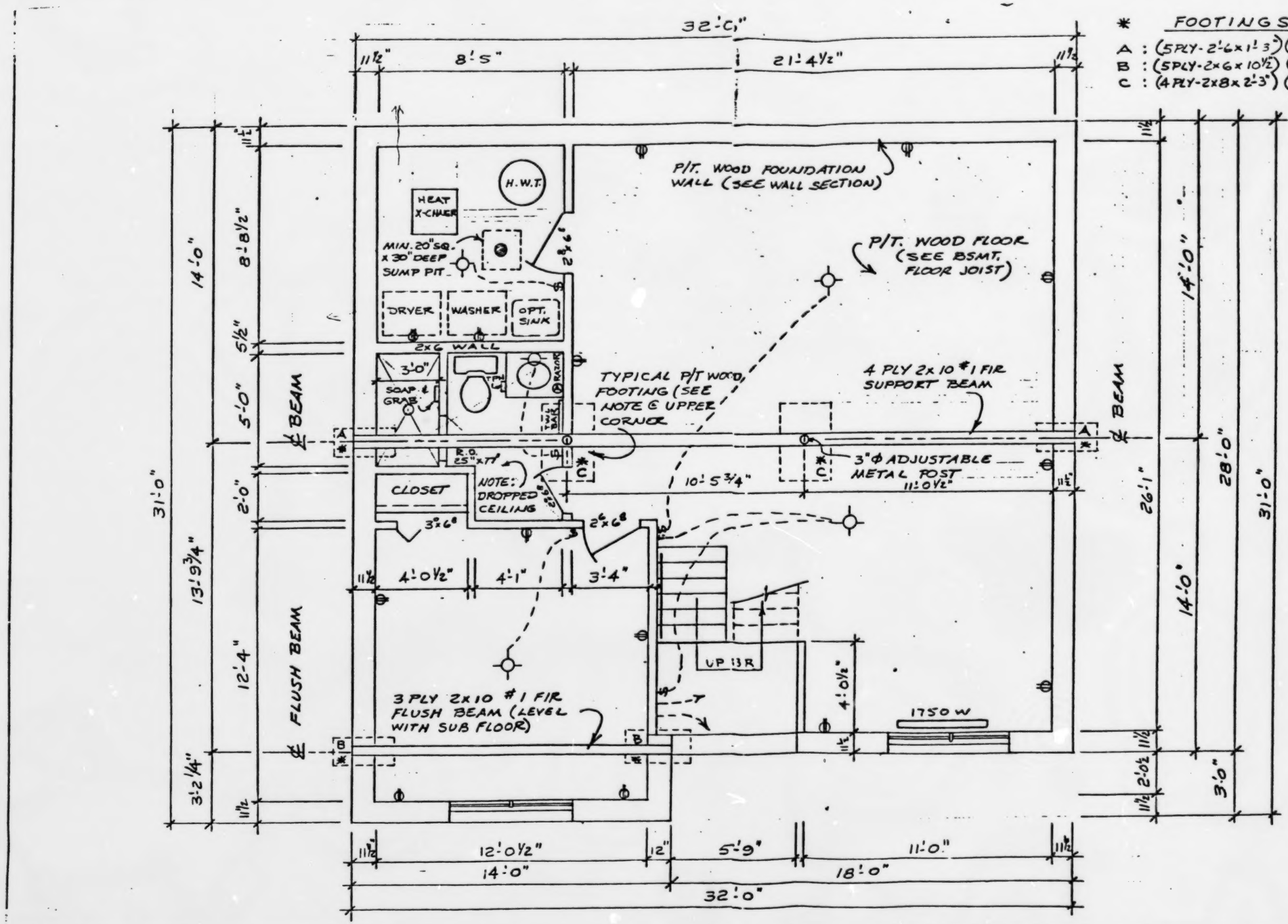
   This period would decrease, making the additions appear more attractive, as electrical rates increase.

APPENDIX A

FLOOR PLANS

AND

WALL CROSS SECTION



DATE: JAN 81

SCALE: ¼"=1'-0"

SHEET NO. 12

SHEET TITLE

BASEMENT PLAN

PLAN: 9/6

ENERGY EFFICIENT HOME

NO. 11. 938 ϕ

Washington Technics

NOTE: ALL WALLS TO BE 3½" UNLESS NOTED OTHERWISE ALL WALLS TO BE STD. HGT.

BALCONY 6'-0" x 4'-0"

BEDROOM #2 12'-0" x 8'-8"

KITCHEN 8'-0" x 9'-8"

DINING 9'-8" x 9'-8"

LIVING ROOM 11'-3" x 16'-0"

MASTER BEDROOM 12'-0" x 12'-4"

FOYER

SCISSOR TRUSSES

ATTIC ACCESS MIN. 20" x 28"

EXHAUST WALL COVER TO BUILT-UP POST SECURED TO TRUSSES

EXHAUST WALL COVER TWL. BAR

2x6 WALL

SOAP & GRAB

T.P.H.

RAZOR

BATH

MR. CLOSET

MRS. CLOSET

CLOS.

LINEN

PANTRY

CAB.

RANGE

FRIDGE

COATS

ARCH

DN.

UP

1000 W

1500 W

8'-0½"

9'-4½"

8'-7½"

8'-1"

12'-0"

14'-0"

2'-4½"

18'-0"

32'-0"

31'-0"

28'-0"

16'-0"

12'-4½"

8'-8"

5'-0"

5½"

DATE - JAN 81

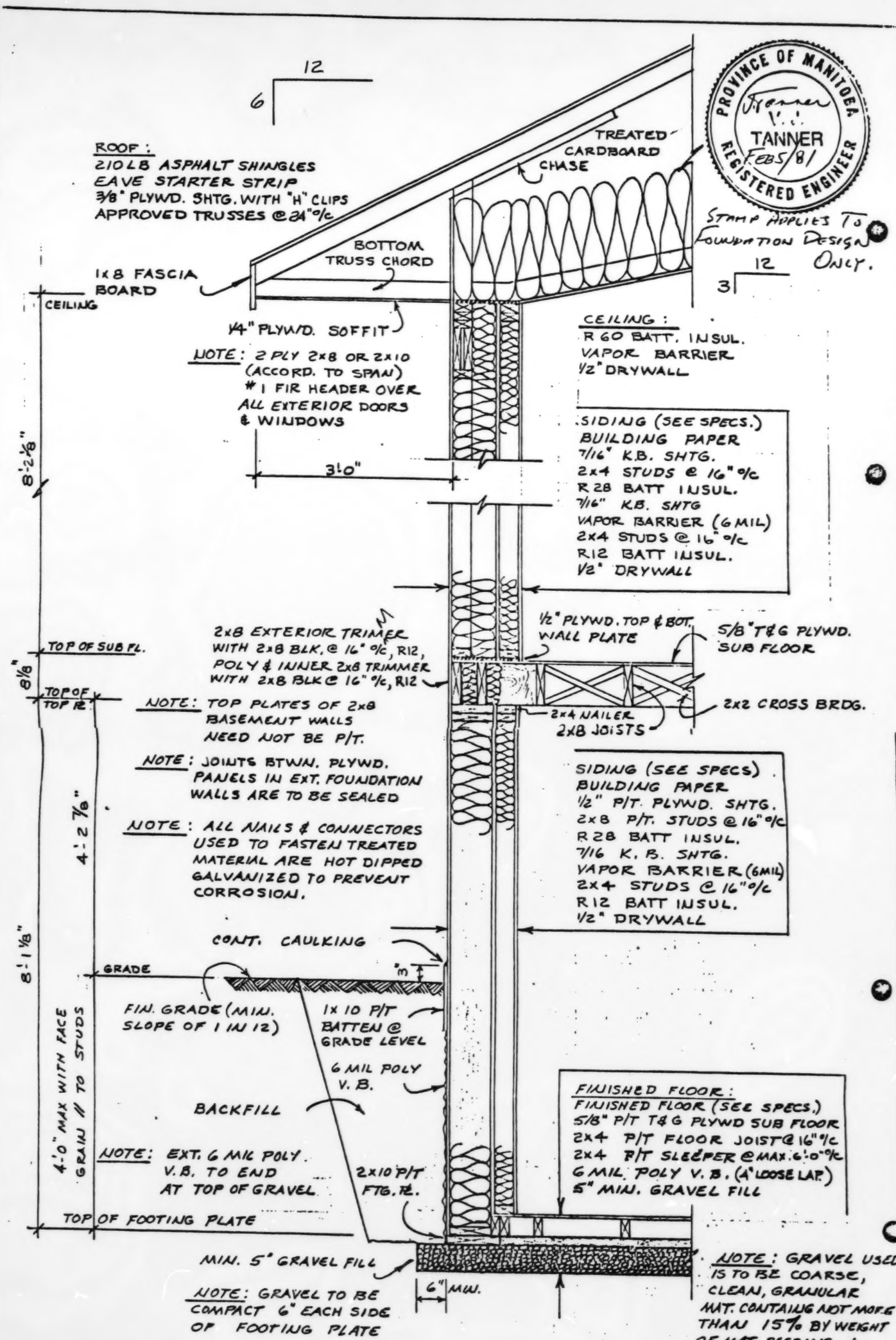
SCALE - 1/4"=1'-0"

SHEET TITLE

916 ENERGY EFFICIENT HOME 938 sq. ft.

PLAN:

REGENCY HOMES


12
6
ROOF :
210LB ASPHALT SHINGLES
EAVE STARTER STRIP
3/8" PLYWD. SHTG. WITH "H" CLIPS
APPROVED TRUSSES @ 24" o/c
TREATED CARDBOARD CHASE
BOTTOM TRUSS CHORD
1x8 FASCIA BOARD
CEILING
1/4" PLYWD. SOFFIT
NOTE: 2 PLY 2x8 OR 2x10 (ACCORD. TO SPAN) #1 FIR HEADER OVER ALL EXTERIOR DOORS & WINDOWS
3'0"
8'-2 1/8"
CEILING :
R 60 BATT. INSUL.
VAPOR BARRIER
1/2" DRYWALL
SIDING (SEE SPECS.)
BUILDING PAPER
7/16" K.B. SHTG.
2x4 STUDS @ 16" o/c
R 28 BATT INSUL.
7/16" K.B. SHTG
VAPOR BARRIER (6 MIL)
2x4 STUDS @ 16" o/c
R12 BATT INSUL.
1/2" DRYWALL
PROVINCE OF MANITOBA
J. Tanner
V. J. TANNER
FEB 5/81
REGISTERED ENGINEER
STAMP APPLIES TO FOUNDATION DESIGN ONLY.
12
3
TOP OF SUB FL.
8 1/8"
TOP OF TOP PL.
2x8 EXTERIOR TRIMER WITH 2x8 BLK. @ 16" o/c, R12, POLY & INNER 2x8 TRIMMER WITH 2x8 BLK @ 16" o/c, R12
1/2" PLYWD. TOP & BOT. WALL PLATE
5/8" T&G PLYWD. SUB FLOOR
2x4 NAILER
2x8 JOISTS
2x2 CROSS BRDG.
NOTE: TOP PLATES OF 2x8 BASEMENT WALLS NEED NOT BE P/T.
NOTE: JOINTS BTWN. PLYWD. PANELS IN EXT. FOUNDATION WALLS ARE TO BE SEALED
NOTE: ALL NAILS & CONNECTORS USED TO FASTEN TREATED MATERIAL ARE HOT DIPPED GALVANIZED TO PREVENT CORROSION.
4'-2 7/8"
SIDING (SEE SPECS)
BUILDING PAPER
1/2" P/T. PLYWD. SHTG.
2x8 P/T. STUDS @ 16" o/c
R 28 BATT INSUL.
7/16 K. B. SHTG.
VAPOR BARRIER (6MIL)
2x4 STUDS @ 16" o/c
R 12 BATT INSUL.
1/2" DRYWALL
8'-1 1/8"
CONT. CAULKING
GRADE
"m"
FIN. GRADE (MIN. SLOPE OF 1 IN 12)
1x 10 P/T BATTEN @ GRADE LEVEL
6 MIL POLY V. B.
BACKFILL
4'-0" MAX WITH FACE GRAIN // TO STUDS
NOTE: EXT. 6 MIL POLY. V.B. TO END AT TOP OF GRAVEL
2x10 P/T FTG. PL.
TOP OF FOOTING PLATE
FINISHED FLOOR :
FINISHED FLOOR (SEE SPECS.)
5/8" P/T T&G PLYWD SUB FLOOR
2x4 P/T FLOOR JOIST @ 16" o/c
2x4 P/T SLEEPER @ MAX. 6'-0" o/c
6 MIL. POLY V. B. (4" LOOSE LAP.)
5" MIN. GRAVEL FILL
MIN. 5" GRAVEL FILL
6" MIN.
NOTE: GRAVEL TO BE COMPACT 6" EACH SIDE OF FOOTING PLATE
NOTE: GRAVEL USED IS TO BE COARSE, CLEAN, GRANULAR MAT. CONTAINING NOT MORE THAN 15% BY WEIGHT OF MAT. PASSING A #10 SIEVE

Kensington Homes	PLAN: 916 ENERGY EFFICIENT HOME SQ. FT. 938 ft²	SHEET TITLE TYP. EXT. WALL SECTION	DATE: JAN 81 SCALE: 3/4" = 1'-0" SHEET NO: 5

APPENDIX B

AIR LEAKAGE

AND

BLOWER DOOR DESCRIPTION

AIR INFILTRATION

IMPORTANCE OF AIR INFILTRATION

All houses experience uncontrolled air infiltration to varying degrees. This provides fresh air for breathing, odor and moisture control, as well as supplying combustion air for appliances such as gas or oil furnaces. Unfortunately, this outdoor air must be heated to room temperature and thus constitutes an additional heating load for the furnace to meet. The magnitude of this load is higher than most people realize. In fact, air infiltration is responsible for 15% to 40% of the total heating bill in most Manitoba homes.

CAUSES AND SOURCES OF AIR INFILTRATION

Air infiltration is produced by three forces: wind, stack effect and mechanical ventilation. Wind action puts the windward side or half of a house under a positive pressure differential (i.e. outdoor air pressure is greater than indoor) causing a net inward flow of air, and the leeward side under a negative pressure differential, creating a net outward air flow. Stack effect is produced by the indoor to outdoor temperature differential and typically creates a net inflow over the bottom half of the house and an outflow over the top half. Mechanical ventilation accounts for the air admitted to the house to replace air exhausted through kitchen or bathroom fans.

The primary sources of air infiltration (i.e. where the air actually enters or leaves the house) are listed below in their order of importance:

a) around top and bottom sill plates,

b) past electrical outlets on exterior walls,

c) through breaks in the ceiling vapor barriers caused by ceiling light fixtures, attic hatches, interior partitions, plumbing stacks, etc.

d) through leaky doors and windows,

e) other miscellaneous sources such as chimneys, fireplaces, floor drains, etc.

THE BLOWER DOOR ASSEMBLY

COMPONENTS

The blower door assembly consists of four major components: a collapsible door which fits into the door opening of the test house, an electric blower with speed control to exhaust air from the structure, a bell mouth nozzle to measure the quantity of air being exhausted and a house pressure manometer to determine the indoor to outdoor pressure differential created by the blower. These are illustrated in Figure B1.

Collapsible Door - The door is constructed of plywood and is composed of three hinged sections. When fully extended, its dimensions are 81 cm x 203 cm (32" x 80") - the standard residential door size. The unit is held firmly in place in the opening by four wooden brackets so that a tight seal exists between the door and the opening. When fully collapsed, the unit can be easily transported by one man.

Blower - The blower is permanently bolted to the centre of the collapsible door and has a capactiy of approximately 566 1/s (1200 cfm) which is adjustable with the speed controller. The unit exhausts air from the house through the nozzle.

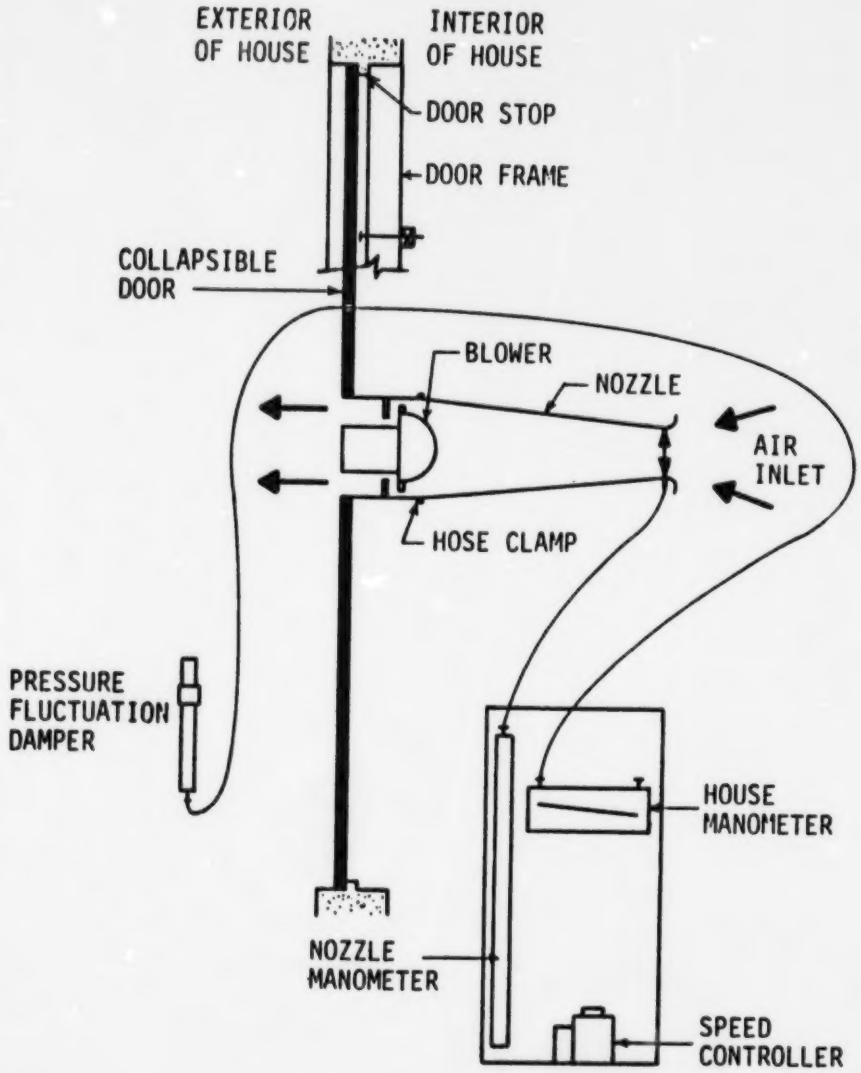
Nozzle - The bell mouth nozzle is constructed of fibreglass with metal flow straighteners. It is affixed to the blower before the test by a single clamp. The quantity of air being exhausted through the blower is accurately determined by measuring the pressure drop at the throat section of the nozzle. Pressure taps at the nozzle throat are hooked up to the low pressure side of a vertical manometer by a single flexible tube. The high pressure side of the manometer is left open to the atmosphere. The nozzle manometer is located in a wooden carrying case with the house pressure manometer.

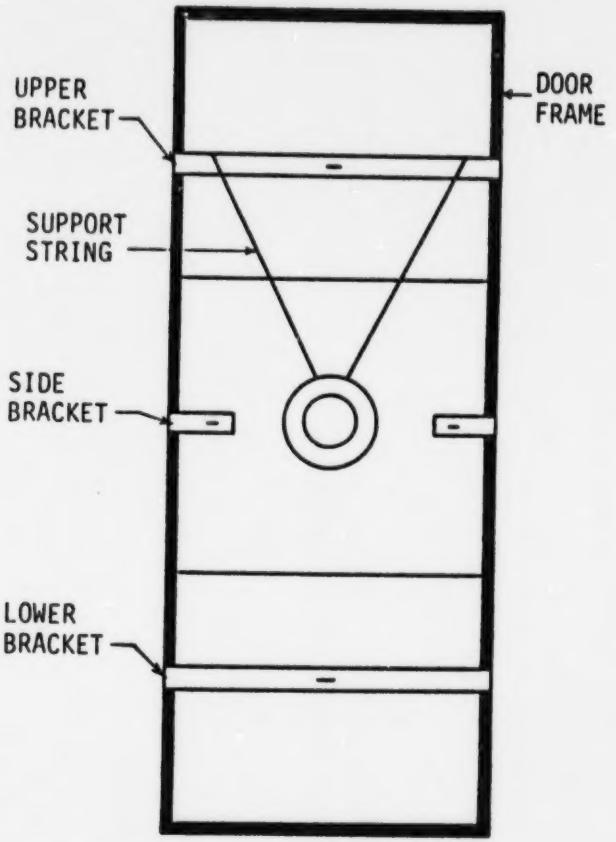
House Pressure Manometer - This measures the actual indoor to outdoor pressure difference created by the exhaust fan. The indoor tap is left open to room air and the outdoor tap is connected to a pressure fluctuation damper through a 6 m (20') flexible tube. The damper is placed in the yard at a location where the effects of wind turbulence are minimized.

OPERATION

The use of the blower door assembly is straightforward; an entire test from arrival at the house to departure can be performed by one man in one and one-half hours.

Normally, two tests are conducted on each house. The first is done with the chimney and other vents open to simulate the actual operating condition of the house and the second with them closed to evaluate the integrity of the wall, ceiling and floor vapor barriers. The first test may not prove necessary if the investigator is only concerned with studying how uncontrolled leakage through the vapor barrier can be reduced.





INTERIOR VIEW

BLOWER DOOR ASSEMBLY GENERAL ARRANGEMENT

FIGURE B1

APPENDIX C

AIR LEAKAGE TEST RESULTS

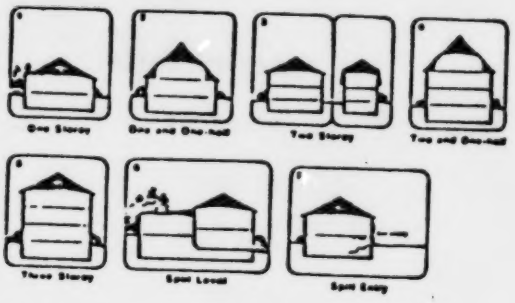
DATE: April 2, 1981
ADDRESS: 15 Crittenden
OWNER: Kensington

HOUSE DESCRIPTION

1. Year house built? (Approx. date) 1981

2. Type of house?

   If house has an addition that gives it more than one style, mark the style of the main house.



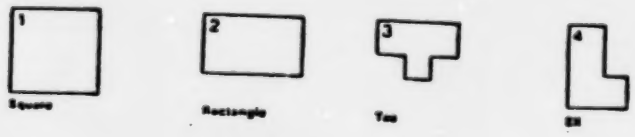
one storey	
one & half storey	
two storey	
two & half storey	
three storey	
split level	
split entry	X

3. Basement:

fully heated	X
partial heated	
area	
crawlspace (unheated)	

4. Basic shape of the ground floor?

   Disregard any unheated porches, garages, sheds, etc. and any small irregularities in shape.



square	X
rectangle	
tee	
ell	
other	

5. Gross heated floor area of the house? (Not including basement) {(30.666 x 29.666) - 54}/10.76 (inside vapour barrier) 79.53 m^2

6. How are exterior walls constructed?

wood frame	X
solid masonry or stone	
plank frame or solid log	

7. If wood frame, what veneer or siding?

brick	
wood	
aluminum	
stucco	X

8. Perimeter of heated portion of house: 38.4m
   2 (31 + 32) 13.28
9. Exposed house surface area: 239 m^2
   (based on vapour barrier area)
10. House Volume: 419.9 m^3
    (inside vapour barrier)
11. Number of windows of type:
    (each window frame constitutes one window)

sealed units	5
casement	7
slider	
awnings	

Tightness of Windows:

tight	X
average	X
loose	

12. How is house insulated?
    (thickness & material)

Roof: RS1 10.57

Walls: RS1 6.64

Basement: RS1 5.42

13. Type of vapour barrier if any:
    6-mil poly, attempted air tight standards

14. Condition of weatherstripping:

good	X
average	
poor	

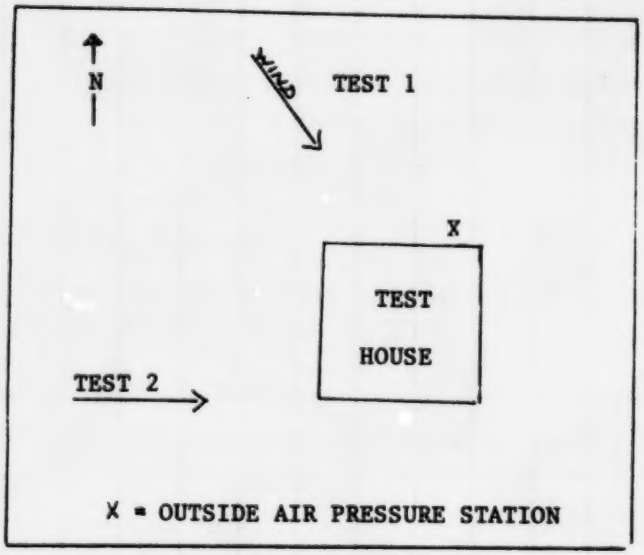
15. Type of heating:

gas	
oil	
electric	X
other	

16. If there are fireplaces, how many?

17. Is the header space between floor joists accessible?
    YES

18. Sketch pertinent features affecting exposure of house to wind, and show prevailing wind direction.



TEST #2

Residential Air Leakage Test Data

Date: October 21, 1981
Address: 15 Crittenden
Name of Owner: Kensington Homes

Atmospheric Conditions: Overcast
Temperature: -2 C
Wind: 20 km/h

House Pressure (Pascals) A	Nozzle Pressure (Pascals) B	Air Flow (Litres/Second) C	House Pressure (Pascals)	Nozzle Pressure (Pascals)	Air Flow (Litres/Second)
	PASCALS				
20	.045 (11.21)	48.91			
39	.125 (31.14)	81.31			
61	.250 (62.28)	114.8			
81	.350 (87.19)	135.7			
105	.520 (129.5)	165.2			
90	.400 (99.64)	145.0			
70	.290 (72.24)	123.6			
50	.190 (47.33)	100.1			
30	.090 (22.42)	69.05			
9	.020 (49.82)	32.67			

$y = 0.8459$
$m = 0.6747$
$r^2 = 0.9954$
Q50 = 98.25
Q10 = 33.17

A, B, C - see following page for explanations

December/80

APPENDIX C

TEST #2 - October 21, 1981

House Complete

$Q = 7.013\ \Delta p\ 0.6747$ (see D)

$r = 0.9977$ (minimum acceptable value = 0.9800) (see E)

$Q_{50} = 0.84$ AC/hr (interpolated from test data) (see F)

$Q_{10} = 0.28$ AC/hr (extrapolated from test data) (see F)

A. House Pressure

This is the envelope pressure produced by the blower door assembly and is measured in Pascals.

B. Nozzle Pressure

This is the pressure created by the air flow at the throat of the nozzle, and is measured in Pascals.

C. Air Flow Rate

The nozzle is a carefully calibrated, long radius ASME nozzle with known characteristics. The relationship between the nozzle pressure and air flow rate has been determined in the laboratory and the nozzle pressure is then used to calculate the corresponding air flow rate.

D. Flow Rate Calibration

Calibration formula used to calculate Q from pressure differential data.

E. Correlation Coefficient (r)

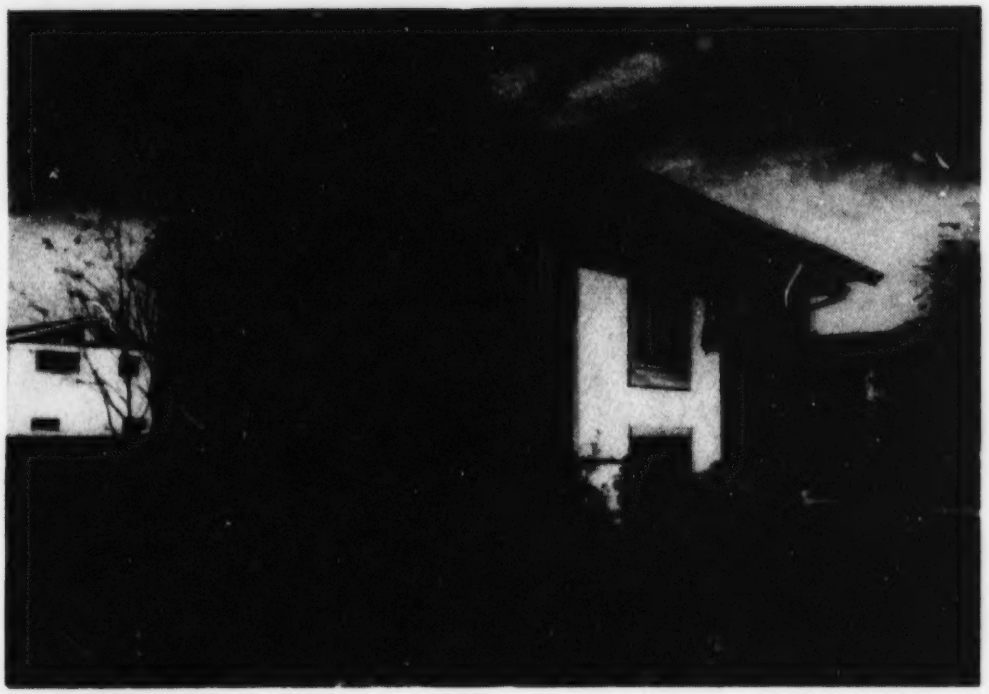
In order to determine the accuracy of the pressurization data, some indication of how well the points 'fit' on a straight line must be included. The determination of the correlation coefficient is a complicated but very accurate means of ensuring an acceptable 'fit'. If the value of r is less than 0.9800 the leakage test must repeated.

F. Air Change Rate

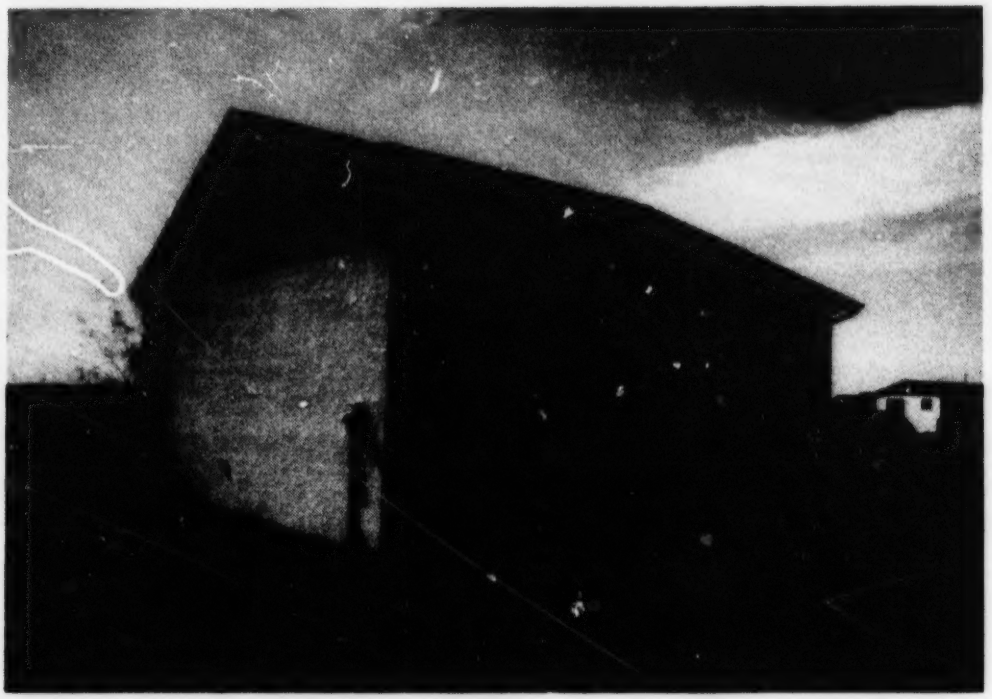
The air change rate is the number of time that the entire air volume within the structure changes each hour at a specific pressure differential. The pressure differential of 50 Pascals is selected to conform with the reference pressure used internationally to report air change rates. This value is determined by dividing the air flow rate per hour at a 50 Pascal pressure differential by the heated volume of the structure.

A P P E N D I X E

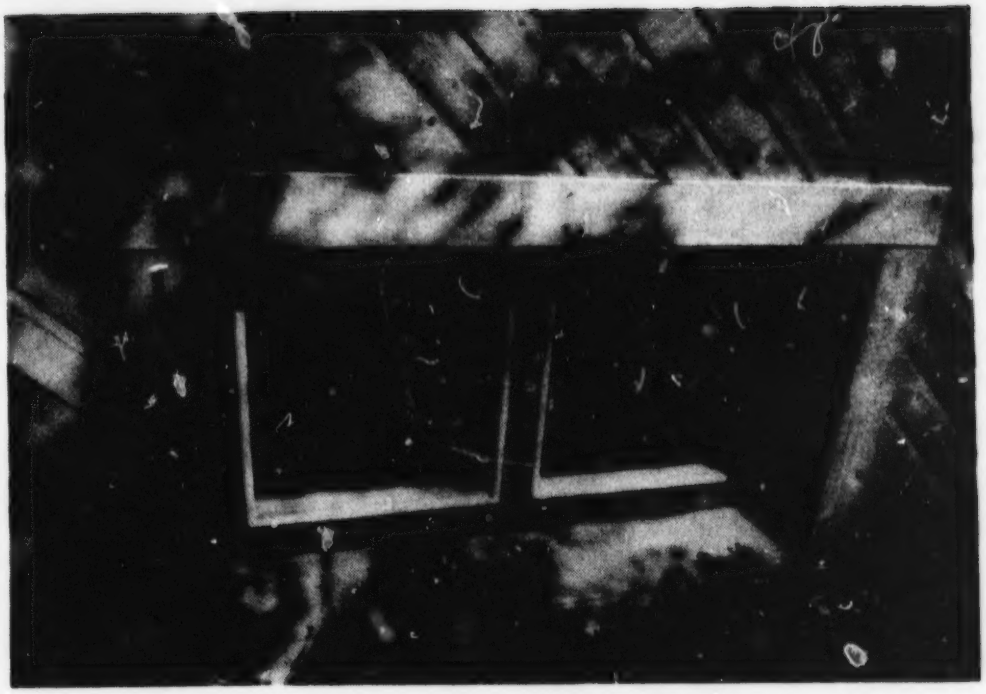
PHOTOGRAPHS



Front (south side) view of house

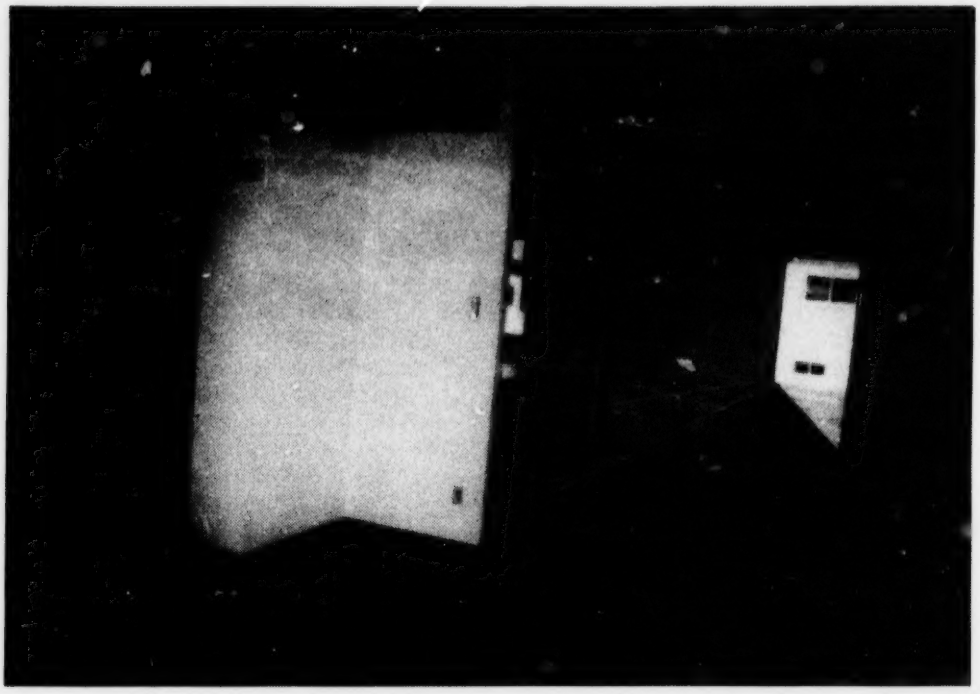


Rear (north side) view



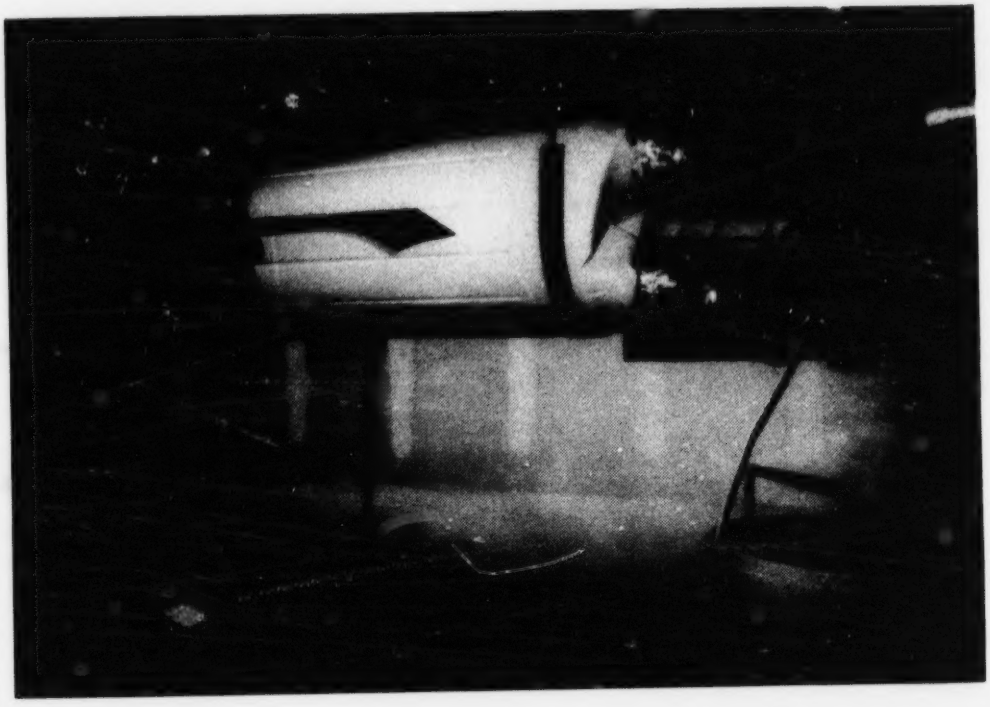
Front casement window

Living room and entrance staircase

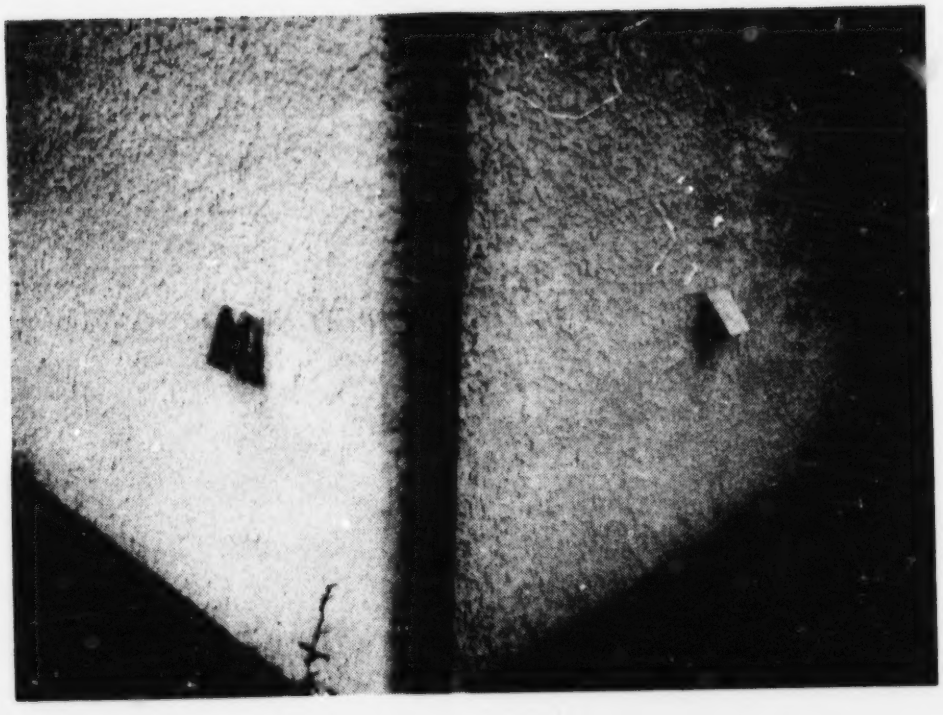


View of dining room with rear doorway and window

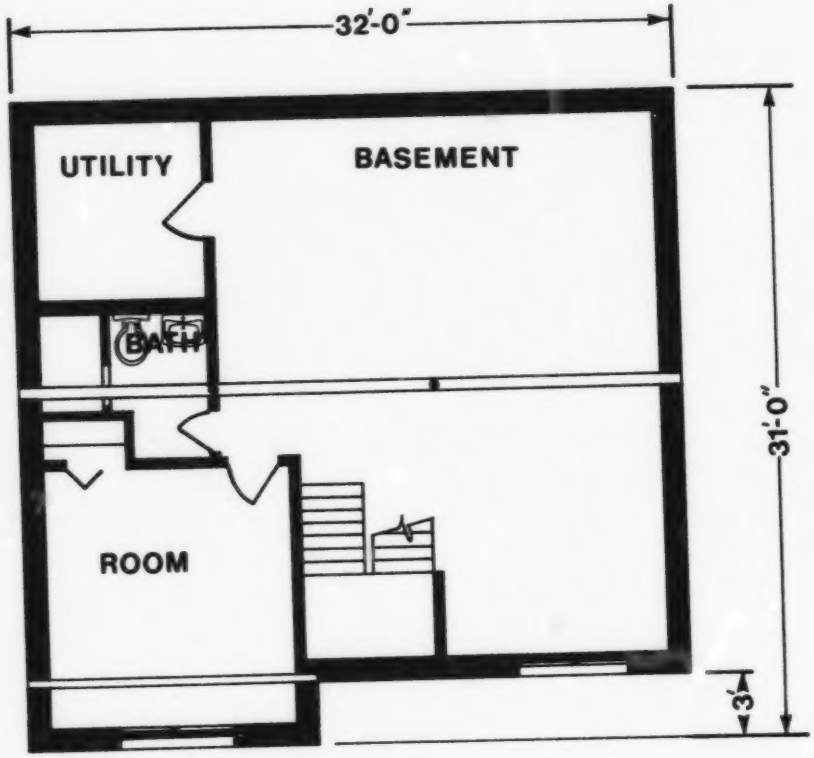
Basement



Enercon air-to-air heat exchanger installation



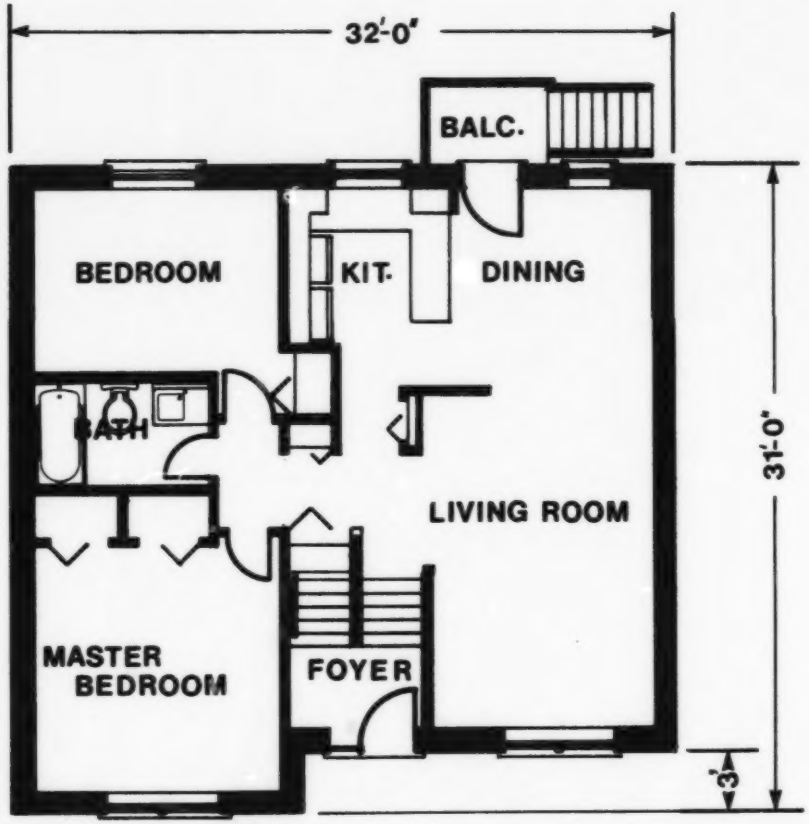
Heat exchanger inlet and vent



BASEMENT PLAN

KENSINGTON HOMES

ENERGY EFFICIENT HOMES
scale: $\frac{1}{8}$" - 1'-0"



MAIN FLOOR PLAN

KENSINGTON HOMES

ENERGY EFFICIENT HOMES
scale: $\frac{1}{8}$" - 1'-0"

Canada

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

MANITOBA

DEPARTMENT OF ENERGY AND MINES

MG-9979

POOR

QUALITY

ORIGINAL